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BIOACTIVE CONTENTS AND FRUIT TRAITS OF SOME APPLE CULTIVARS GROWN IN KAYSERI

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Abstract: This study was carried out to determine the physical properties, biochemical and bioactive compounds of different apple cultivars grown in Yahyalı district of Kayseri province. The plant material of the research consisted of apple cvs. 'Scarlet Spur', 'Starking Delicious', 'Starkrimson Delicious', 'Golden Delicious', and 'Super Chief'. In the study fruit weight, length, width, firmness, soluble solid contents (SSC), titratable acidity (TA), vitamin C, total phenolics, total flavonoids, and antioxidant activities (DPPH and FRAP assays) were investigated. In the findings, significant differences were determined between the fruit characteristics of the cultivars. The highest fruit weight (289.96 g) and length (32.61 mm) were measured from 'Scarlet Spur', while the highest fruit width (34.86 mm) was measured from 'Scarlet Spur' and 'Starkrimson Delicious'. The SSC was determined between 11.65 ('Super Chief')-14.30% ('Starkrimson Delicious'), and TA between 0.47% ('Super Chief')-1.13% ('Golden Delicious'). The highest vitamin C content was measured in 'Starking Delicious' cultivar (66 mg100 g^{-1}) compared to the others. In terms of total phenolic content, 'Scarlet Spur' (38.2 g GAE L^{-1}) and 'Super Chief' (36.5 g GAE L^{-1}) cultivars had the highest values, while 'Super Chief' had the highest values in terms of total flavonoids (23.5 g QE L^{-1}), and antioxidant activity (FRAP, 490.7 mmol TE L^{-1}; DPPH, 1145.9 mmol TE L^{-1}). As a result, it was revealed the differences between the physical, biochemical, and bioactive contents of apple cultivars grown in Yahyalı district of Kayseri province.

Keywords: Antioxidant, Firmness, *Malus domestica*, Total phenolics, Vitamin C

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1. Introduction

The Apple is one of the fruit species with high economic value and consumption preference, which is widely grown in our country and worldwide (Çorumlu, 2010; Uzun et al., 2016). The spread of cultivation in large areas in Türkiye is seen as the favorable ecological conditions (Öztürk and Öztürk, 2016; Şensoy and Bostan, 2019). For this reason, Türkiye is an important apple production center and its apple products are valuable both in the domestic market and in exports. So, determining the physical and biochemical properties of different cultivars in regional cultivation is essential in obtaining fruits with high market value for producers and consumers.

Apples can be stored longer than many other types of fruit (Öztürk et al., 2018). This ensures the quickly and cheaply availability of fruit for people almost throughout the year. Apple exhibits an increasing consumption trend due to its rich nutritional contents including bioactive ingredients for health. Apple contains many biochemical components, such as phenolic compounds, antioxidants, and vitamin C, which are important for human health and effectively prevent many diseases (Teshome et al., 2023). In particular, its antioxidant activity helps protect cells from oxidative damage (Deuchande et al., 2023). Consequently it provide resistance against cancer and cardiovascular diseases, obesity, and other chronic diseases (Millán-Laleona et al., 2023). However, known that cultivars have a significant effect on the biochemical content.

The physical properties of fruits play an important role in consumption preference. In addition, it determines the suitability for industrial use (Özçağıran et al., 2005). However, it has been stated that ecological factors may cause some changes in the physical properties of fruits (Öztürk and Öztürk 2016). For this reason, it is necessary to determine the cultivars physical characteristics and select the appropriate cultivars for the region (Turan and Karlıdağ, 2022). This way, a higher quality product is obtained, a higher economic profit is provided based on the producer, and a contribution to the country's economy is provided. In addition, easier marketing of the quality products obtained is of particular importance for producers (Kaya et al., 2022).

This study was carried out to determine the physical properties, biochemical and bioactive compounds of different apple cultivars grown in Kayseri province. Within the scope of the study, it aims to help the producers who grow apples or plan to grow in the region in selection of ideal apple cultivars.

2. Materials and Methods

2.1. Plant Materials

This research was conducted in 2022, in the Yahyalı district of Kayseri province. The research material was obtained from the orchard of a person who produces commercially production in this area. The area where the research was conducted is a very flat area with an average of 1-2% slope. The terrestrial climate prevails in the district. The average temperature is 20 °C in summer and -18 °C in winter. The plant material of the research consists of 'Scarlet Spur', 'Super Chief', 'Golden Delicious', 'Starkrimson Delicious', and 'Starking Delicious' cultivars grafted on MM106 rootstock at seven years old. The orchard was established north-south, and the soil structure is sandy loam. All cultural processes in the orchard were performed at a similar level and in a way for each cultivar.

2.2. Methods

The study was designed as three replications with five plants in each repetition. Approximately 10 kg of fruit from trees of each cultivar was collected by hand to represent the tree. Harvesting was carried out when the fruits reached commercial maturity (based on days after full blooming for each cultivars). The harvested fruit were placed in the crates in a single row and transferred to the postharvest physiology laboratory (24±2 °C and 80±5% relative humidity) of the department of horticulture at Ordu University without wasting time.

2.3. Observations

2.3.1. Fruit weight, length, width, and firmness

Measurements were carried out on 30 fruits at each replications for each cultivar, with three replications for a total of 90 fruit. Fruit weight was measured using a digital balance with an accuracy of 0.01 g (Radwag PS/C/1 model, Poland). Dimensional properties were measured with a 0.01 mm precision digital caliper (Mitutoyo CD-6CSX, Tokyo, Japan). The firmness expressed in N after being measured with a hand penetrometer (FT-327, Effegi, Italy) with an 11.1 mm tip (Ozturk et al., 2018).

2.3.2. Soluble solid contents (SSC), titratable acidity (TA) and vitamin C

A total number of 45 fruits (15 for each test) were separated for SSC, TA and vitamin C analysis. The separated fruit were crushed with a blender (Model: Promix HR2653 Philips). The SSC was determined using a digital refractometer (Atago, PAL-1, USA). For TA measurement, 15 mL of extract was mixed with 15 mL of distilled water and the amount of 0.1 mol L^{-1} NaOH (sodium hydroxide) required to titrate the solution to pH 8.1 was recorded as titratable acidity (mg malic acid 100 mL^{-1}). To determine the vitamin C (mg 100 g^{-1}) of the samples, approximately 0.5 mL of the extract was mixed with 0.5% oxalic acid to a final volume of 5 mL. Vitamin C test strips (Catalog no: 116981, Merck, Germany) were used for the measurement (Ozturk et al., 2019).

2.3.3. Total phenolics, total flavonoids, antioxidant activity

During the measurement, 10 fruit were taken from each replication, and washed with distilled water. The fruit were then homogenized in a blender for 5 min. Approximately 30-40 mL of fruit pulp was placed into a 50 mL tube. The prepared tubes were kept at -20°C until the day of analysis. Before the analysis, the frozen samples were thawed for approximately 5 h at room temperature (21 °C). Pulp and juice were separated from each other by centrifugation at 12,000 × g at 4°C for 30 min. The filtrate, which completely separated from the pulp, was used to determine the content of total phenolics, total flavonoids, DPPH, and FRAP antioxidant activities. Spectrophotometric measurements for total phenolics, total flavonoids, and antioxidant activity were performed using a UV-Vis spectrophotometer (Shimadzu, 1280, Kyoto, Japan). Total phenolics were determined according to the method described by Singleton and Rossi (1965), total flavonoids were determined according to the method described by Chang et al. (2002), and antioxidant activity was determined using two different procedures: 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) assay (Aglar et al., 2017) and ferric ions (Fe^{+3}) reducing antioxidant power (FRAP) assay (Benzie and Strain, 1996). The results were expressed as follows: total phenolics as g GAE (gallic acid equivalent) L^{-1} fresh weight (fw), total flavonoids as g QE (quercetin equivalent) L^{-1} fw, and DPPH-FRAP as mmol Trolox equivalent (TE) L^{-1} fw.

2.4. Statistical Analysis

The normality of the data was tested using the Kolmogorov-Smirnov Test, while Levene's test was utilized for variances homogeneity. Subsequently, an analysis of variance (ANOVA) was conducted to evaluate the data, and Tukey's multiple-comparison test was employed to detect significant differences among the cultivars. All statistical analyses were performed with the aid of SAS software (version 9.1, USA).

3. Results and Discussion

Fruit weight, length, width, and firmness values of the cultivars examined in the study were presented in Table 1. In apples, fruit weight, shape, size, and firmness are important criteria that affect consumer preferences (Drkenda et al., 2021). On the other hand, it is important to know the physical properties of fruit so that the producer can obtain more yielding, higher quality and marketable products (Cătălina et al., 2015). Because it is known that environmental conditions affect these features as well as genetic factors. In this study, differences between cultivars were significant regarding fruit weight, length, and width ($P<0.05$). The lowest fruit weight was determined in 'Starking Delicious' (165.93 g), while the highest was determined in the Scarlet Spur (289.96 g). Similarly, fruit length and width were the lowest in 'Starking Delicious' (26.79 mm and 27.99 mm) and the highest in 'Scarlet Spur' (32.61 mm and 34.86

mm). On the contrary, the lowest firmness was determined in the 'Scarlet Spur' (62.8 N) and the highest in 'Starking Delicious' (75.3 N). The difference between the cultivars in terms of firmness (62.8-75.3) was statistically insignificant (P<0.05). In previous studies carried out in different ecological conditions, Jemrić et al. (2003) were determined fruit weight 173.59-213.78 g, and firmness 64.13-67.66 N in 'Golden Delicious' in Croatia ecology; Karşı and Aslantaş (2016) were determined fruit weight 159.67 g, fruit width 73.8 mm, and fruit length 67.6 mm in 'Golden Delicious' in Erzurum ecology; Turan and Karlıdağ (2022) were determined fruit weight 139.31-139.87 g, fruit length 54.09-60.13 mm and firmness 44.12-49.03 N in 'Golden Delicious' in Malatya ecology; Özongun et al. (2014) were determined fruit weight 249 g, fruit width 82 mm, fruit length 73 mm, and firmness 68.82 N in 'Scarlet Spur' in Isparta ecology; Bolat et al. (2019) were determined fruit weight 157.5 g, fruit width 68.7 mm, fruit length 67.5 mm, and firmness 50.01 N in 'Scarlet Spur' in Antalya ecology; Uzun et al. (2022) were determined fruit weight 251.40 g, fruit width 78.37 mm, and fruit length 72.97 mm in 'Scarlet Spur' in Ordu ecology. Accordingly, it is seen that the findings obtained from this study have similarities with the results in the literatures. It is thought that ecological conditions and cultural practices such as genetic factors (Ateş and Öztürk, 2022), rootstocks (Ercişli et al., 2000; Yaman et al., 2022), pruning (Ates et al., 2022), fertilization (Bai et al., 2019), application of bio-stimulants (Sîrbu et al., 2023), and irrigation (Mpelasoka et al., 2000) can affect the physical properties of fruits.

The SSC, TA and vitamin C values of the cultivars examined in the study are presented in Table 2. Regarding these characteristics, the differences between the cultivars were statistically significant (P<0.05). While these features are effective on the maturity status of the fruits and the determination of the harvest date, they are also important in terms of taste and flavor formation. It is reported that the maturity status of fruits is related to ecological conditions (Güneyli and Onursal, 2014) and genetic factors (Bolat et al., 2019). In this study, the differences between the cultivars regarding biochemical properties were statistically significant (P<0.05). The lowest SSC and TA content were found in 'Super Chief' (11.65% and 0.47%), the highest SSC in 'Starkrimson Delicious' (14.3%), and the highest TA in 'Golden Delicious' (1.13%). Vitamin C was the lowest in 'Golden Delicious' (48 mg 100 g^{-1}) and the highest in 'Starking Delicious' (66 mg 100 g^{-1}). In previous studies carried out in different ecological conditions, Jemrić et al. (2003) were determined SSC between 12.11-13.38%, and between TA 0.39-0.41% in 'Golden Delicious' in Croatia ecology; Ghafir (2009) was determined SSC of 14,75%, and TA of 0.20% in 'Starkrimson' in Libya ecology; Maqsood et al., (2013) were determined vitamin C of 11.63-12.3 mg 100 g^{-1}, and TA of 0.31% in 'Starkrimson' and 'Starking Delicious' cultivars in Pakistan ecology.

Phenolic compounds and antioxidant activity, which positively affect human health, are secondary metabolites (Chen et al., 2013) found in fruits (Ozturk et al., 2016) or other parts of plants (Prakash et al., 2007). These contents can vary according to the species and depending on the variety and environmental factors. Total phenolic contents (TPC), total flavonoid contents (TFC), and antioxidant activities (DPPH and FRAP assays) of the cultivars examined in the study were presented in Table 3. Regarding these characteristics, the differences between the cultivars were statistically significant (p<0.05). In the study, the highest TPC were obtained from 'Scarlet Spur' (38.2 g GAE L^1) and 'Super Chief' (36.5 g GAE L^{-1}) cultivars, while the lowest was found in 'Golden Delicious' (17.7 g GAE L^{-1}). TFC were highest in 'Super Chief' (23.5 g QE L^{-1}) and lowest in 'Starking Delicious' (14.5 g QE L^{-1}). According to DPPH and FRAP assays, the antioxidant activity was the highest in 'Super Chief' and the lowest in 'Golden Delicious'. Antioxidant activity of the 'Super Chief' cultivar was determined as 490.7 mmol TE L^{-1} according to the DPPH test and 1145.9 mmol TE L^{-1} according to the FRAP test. Similar to our study, TPC (Jindal et al., 2002; Maqsood et al., 2013; Turan and Karlıdağ, 2022), TFC (Awad et al., 2000), and antioxidant activities (Petkovsek et al., 2007; Vieira et al., 2011; Bahukhandi et al., 2019) show significant variation among cultivars. Plants contain essential ingredients both as a source of health and nutrients. Ingredients like bioactive compounds found in fruits are inexpensive and easily accessible. The amount of these bioactive contents varies depending on species-cultivars (Mertoğlu and Evrenosoğlu, 2019; Balta et al., 2022), rootstock (Kviklys et al., 2015), fertilization (Çakır et al., 2021), and ecological factors (Öztürk and Öztürk, 2016).

Table 1. Fruit weight, firmness and fruit dimensional characteristics of different apple cultivars grown in Kayseri

Cultivars	Quality characteristics			
	Fruit weight (g)	Length (mm)	Width (mm)	Firmness (N)
Scarlet Spur	289.96 ^{a}	32.61 ^{a}	34.86 ^{a}	62.8
Super Chief	222.30 ^{b}	31.51 ^{ab}	30.38 ^{b}	67.3
Golden Delicious	226.66 ^{b}	30.09 ^{abc}	30.80 ^{b}	72.8
Starking Delicious	165.93 ^{c}	26.79 ^{d}	27.99 ^{b}	75.3
Starkrimson Delicious	239.18 ^{b}	28.91 ^{cd}	34.86 ^{a}	68.3

* Means in the same column with different letters are significantly different according to Tukey's test at P<0.05.

Table 2. Soluble solid contents (SSC), titratable acidity (TA) and vitamin C contents of different apple cultivars grown in Kayseri

Cultivars	Biochemical characteristics		
	SSC (%)	TA (% malic acid)	Vitamin C (mg 100 g^{-1})
Scarlet Spur	12.85 ^{c}	0.64 ^{c}	60 ^{b}
Super Chief	11.65 ^{e}	0.47 ^{e}	59 ^{b}
Golden Delicious	13.65 ^{b}	1.13 ^{a}	48 ^{d}
Starking Delicious	12.35 ^{d}	0.59 ^{d}	66 ^{a}
Starkrimson Delicious	14.30 ^{a}	0.75 ^{b}	53 ^{c}

* Means in the same column with different letters are significantly different according to Tukey's test at P<0.05.

Table 3. Total phenolics (TPC), total flavonoids (TFC) and antioxidant activity (DPPH and FRAP assays) of different apple cultivars grown in Kayseri

Cultivars	Bioactive compounds			
	TPC (g GAE L^{-1})	TFC (g QE L^{-1})	DPPH (mmol TE L^{-1})	FRAP (mmol TE L^{-1})
Scarlet Spur	38.2 ^{a}	16.9 ^{ab}	346.6 ^{bc}	881.6 ^{b}
Super Chief	36.5 ^{a}	23.5 ^{a}	490.7 ^{a}	1145.9 ^{a}
Golden Delicious	17.7 ^{b}	17.7 ^{ab}	37.4 ^{e}	551.6 ^{c}
Starking Delicious	18.3 ^{b}	14.5 ^{b}	240.3 ^{c}	705.9 ^{bc}
Starkrimson Delicious	18.5 ^{b}	19.4 ^{ab}	75.6 ^{d}	936.8 ^{ab}

* Means in the same column with different letters are significantly different according to Tukey's test at P<0.05.

4. Conclusion

As a result, significant differences were determined regarding the physical, biochemical, and bioactive contents of apple cultivars are grown in Yahyalı district of Kayseri province. According to the analysis, 'Scarlet Spur' cultivar stood out regarding physical properties and 'Super Chief' cultivar in case of bioactive contents. In this context, preferring 'Scarlet Spur' and 'Super Chief' cultivars for growing in Yahyalı ecology can be recommended.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	U.A.	B.Ö.	S.U.
C	20	60	20
D	20	80	
S	25	50	25
DCP	60	10	30
DAI	80	10	10
L	60	20	20
W	60	20	20
CR	10	20	70
SR	40	30	30

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

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